TUNISIA SECTION
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SPECIAL INTEREST GROUP IN HUMANITARIAN TECHNOLOGY

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SIGHT Challenge

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الشركة التونسية لصناعات التكرير

Société Tunisienne des Industries de Raffinage

Tunisian Refining Industries Company

IEEE ISET Bizerte Student Branch

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CHAPTER 1: PRESENTATION OF THE COMPANY

The **Tunisian Company of Refining Industries** (STIR) is one of the most important Tunisian companies due to the vitality of its field of activity and its determining role in the national economy.

1.1 General presentation of the STIR

STIR or the Tunisian Society of Refining Industries was created in 1961 following an agreement between the Tunisian State and the Italian group ENI. Its corporate purpose is the refining of crude oil with a view to satisfying the needs of the national market for petroleum products.

Since its Tunisianization in 1975, STIR has become a public company responsible for covering all of the country's needs for petroleum products.

In this context, the activity of importing all fuels was entrusted to STIR in 1999.

In 2001, the needs of the local market, which reached 3.8 million tonnes of all products combined, were covered by STIR's production and import activities. STIR's turnover exceeding 1 billion Tunisian dinars for the first time places it, according to the Economist Maghrébin, and the Economy at the forefront of Tunisian companies.

Aimed to cover all of the country's oil needs, STIR is responsible for importation of oil products. Thus, for a national consumption of 3.746 million tonnes of refined oil, it produces 1.683 million tonnes and imports 2.790 million tonnes.

1.1.1 STIR identity card

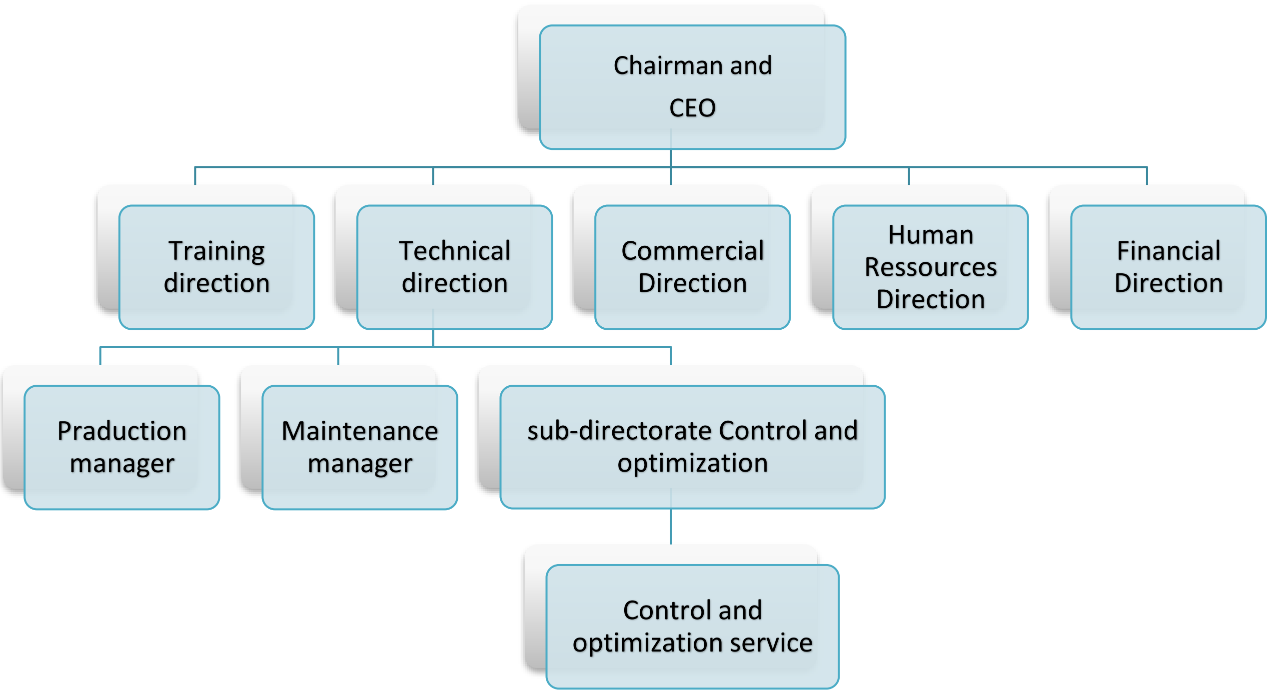
The identity sheet below brings together information on the activity and operation of STIR.

Painting1: STIR identity card

Name	Tunisian Company of Refining Industries
Seat	Zarzouna south of Bizerte 62 km from Tunis
Legal status	Public establishment
Creation	1961 (with the Italian group ENI)
Activity area	Oil refining and import
Number of employees	more than 700 civil servants
Turnover (2017)	4600 MD
Website	http://www.stir.com.tn

1.1.2 Organizational chart

The structure has five main departments described by the following organization chart:



1.1.3 Key Dates & Certifications

With more than a million certificates worldwide, STIR has various certificates.

Painting2: Certificates and key dates

1961	Start of construction by the Italian company SNAM PROGETTI.
1963	Entry into production.
1975	Purchase of foreign participation by the Tunisian State.
1979	Nominal capacity of the refinery increased by 1,600,000 T/year following the REVAMPING of the primary distillation unit.
1984	REVAMPING platforming whose capacity increased from 150,000 to 220,000 T/year.
1989	Debottlenecking of the primary distillation unit as part of an energy saving control program increasing refining capacity to 1,700,000 T/year
1995	Increase in the capacity of the catalytic reforming unit to 250,000 T/year
1997	Extension project: new distillation unit at 3 million tonnes/year.
2014	ISO 17025 laboratory accreditation
2016	ISO 9001 certification2015 version
2017	ISO 27001 certification version 2013

1.2 Petroleum products manufactured

STIR presents a fairly varied range of production which allows it to meet the needs of the national market: LPG (Liquefied Petroleum Gas), Unleaded Gasoline, Normal Gasoline, White Spirit, Lampant Oil, Diesel, Virgin Naphtha, Fuel-Oil, Atmospheric Residue.

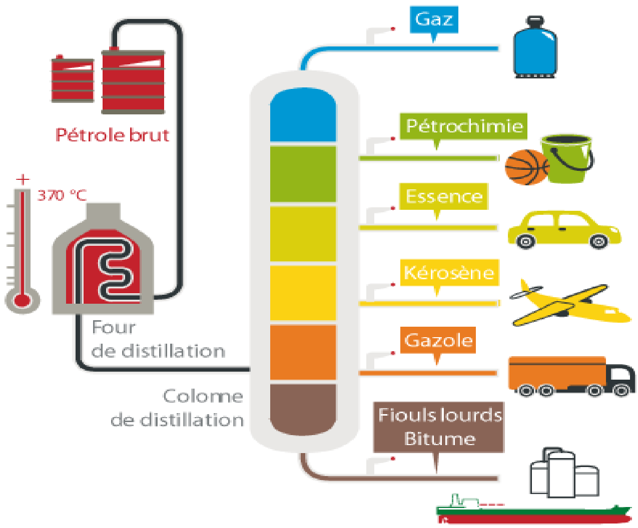
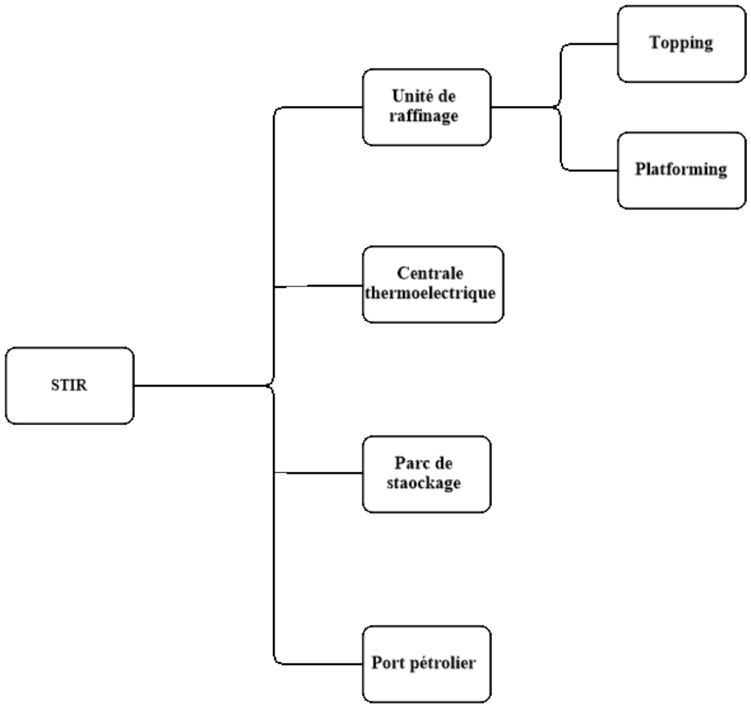


Figure1: Refined petroleum products

1.3 Processes and activities

The only refinery in Tunisia, STIR has a processing capacity of around 1.6 million tonnes per year through its production units which allow it to manufacture, while respecting safety, environment and quality, a whole range of petroleum products and thus meet part of the demand of the local market. [1]

The organization chart below groups together the different units of the factory.



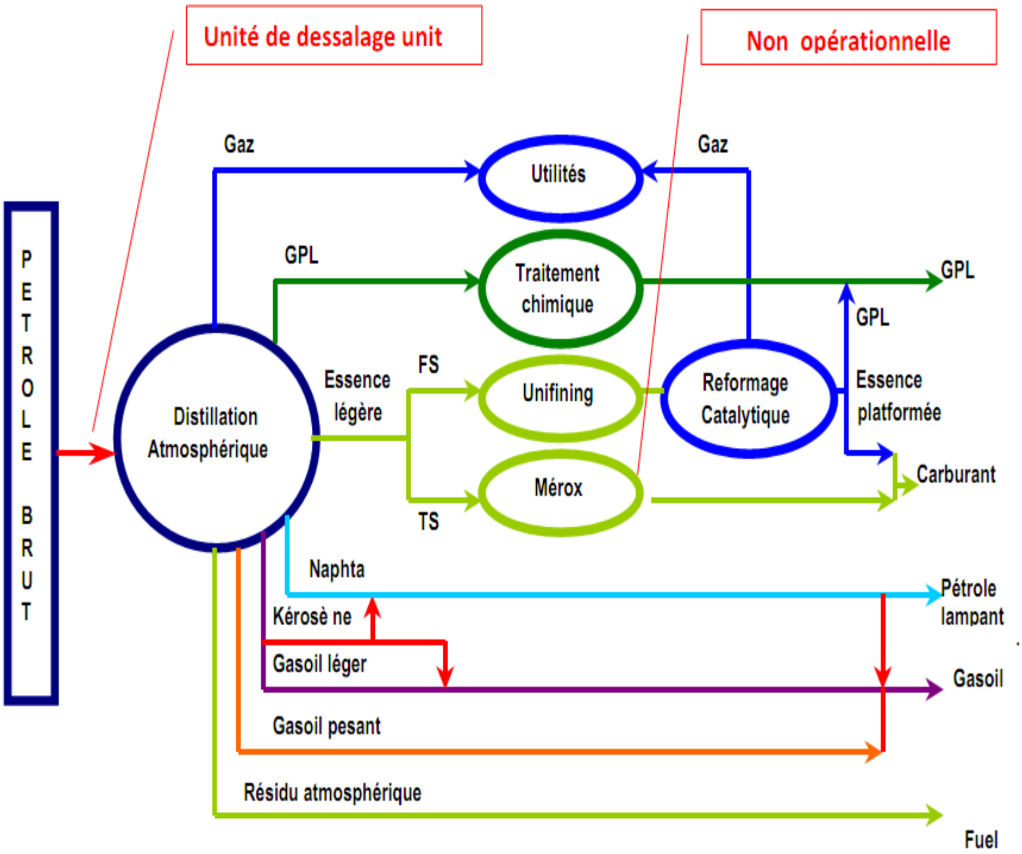


Figure2: Synoptic diagram of the STIR refining process

1.4 Plan and area of intervention

Improving energy efficiency requires a study at the level of the energy producing plant, the objective of which is to determine the origin of the main losses in order to subsequently try to reduce them.

1.4.1 Thermoelectric power station

Definition

The thermal power plant is a power plant that produces electricity from a heat source (coal, gas, fuel oil).

Using the heat source, we heat a fluid which is often water which passes from the liquid state to the gaseous state. The resulting steam thus drives a turbine coupled to an alternator which converts the heat energy contained in the steam into mechanical rotational energy, then into electrical energy thanks to the alternator.

Principle of operation

Thermal power plants operate from natural resources: coal, fuel oil or gas. The fuel, once burned, heats the water located in tubes which line the walls of the boiler.Water transforms into high pressure steam under the influence of heat, which is then sent to the turbine, which first captures the heat energy contained in the steam to convert it into mechanical rotational energy and subsequently drives the alternator to convert this mechanical energy into alternating electric current.

The figure below shows the operating principle of a thermal power plant:

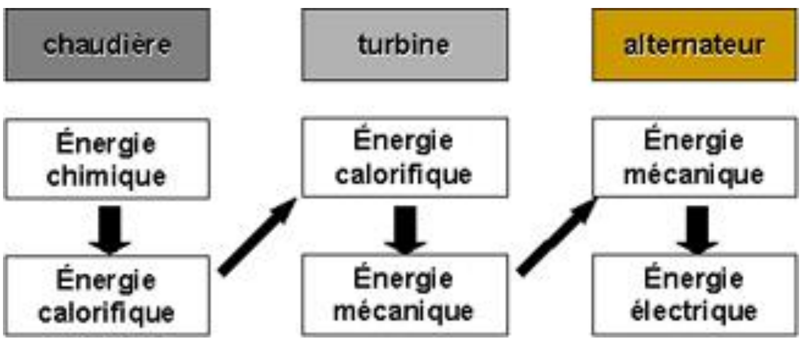


Figure3: Operating principle of a thermal power plant

1.4.2 Description of the main components of a thermal power plant

Thermal power plants contain multiple mechanisms that ensure energy production and directly affect overall efficiency.

These main components are boilers, steam turbines, condensers, pumps, alternators and transformers.

The figure opposite shows the different components of a thermal power plant.

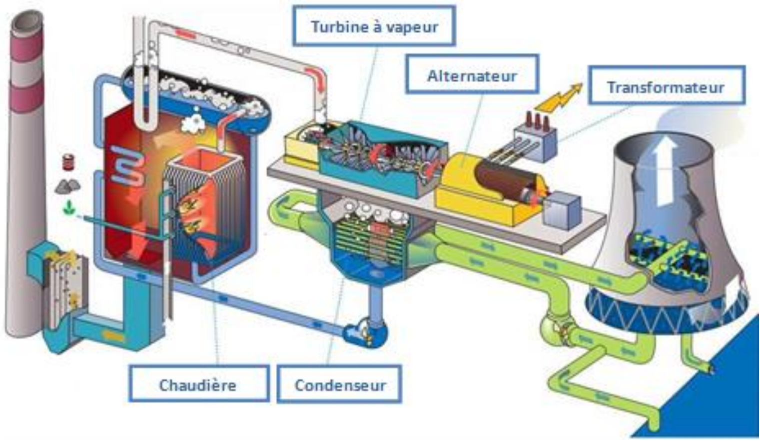


Figure4: Diagram of a thermal power plant

- **Turbines**

A turbine is an industrial engine which uses the energy of a fluid, characterized by its speed and its enthalpy, to provide mechanical energy (i.e. work), which is recovered on an axis (shaft) in rotation. This energy will be used, for example, to drive a pump or an alternator. This fluid can be water (we then speak of a hydraulic turbine), steam (steam turbine), or combustion gases (gas turbine).

The turbine used in the power station in question is a steam turbine.

- **Steam turbine**

The steam turbine is an external combustion engine. As a result, all fuels (gas, fuel oil, coal, waste, residual heat) can be used to supply it with steam produced, for example, from a boiler or available at the output of an industrial process.

There are several types of steam turbines, the following figure represents the diagrams of these different categories:

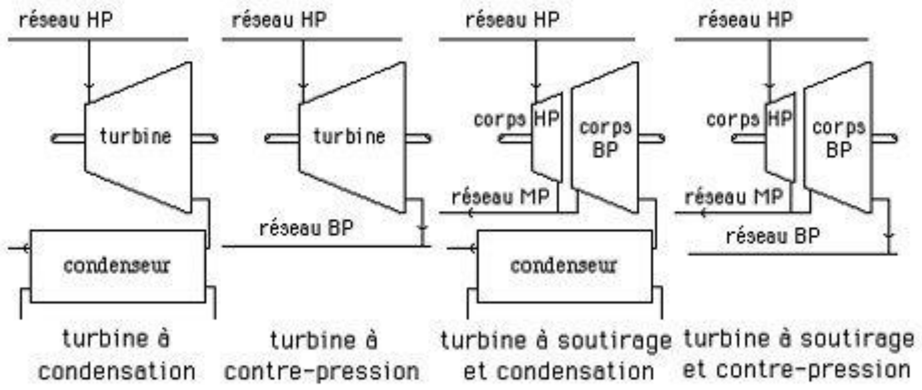


Figure5: Categories of steam turbines

- **Boilers**

Boilers, also called steam generators, are static equipment, which enable the continuous transfer of thermal energy to a heat transfer fluid (heat carrier). Thus, any device producing hot water, water vapor, or superheated water is considered a boiler. Devices that change the temperature of a thermal fluid through combustion are also considered boilers.

There are two main categories of boilers, classified according to the fluids circulating inside the tubes: Fire tube boilers and water tube boilers; In the first, the flame develops in a corrugated hearth tube, then the smoke travels through the tubes and the water is outside.

In the seconds, which we will detail below, the flame develops in a hearth lined with tubes which absorb the radiation. A second bundle of tubes receives the heat from the fumes by convection. The water circulates through the network of tubes, by natural or forced convection, between two balloons placed one above the other, it thus rises in the tubes subjected to the radiation, and descends through the convection beam.

The water tube boiler has two tanks called the distributor tank, at the bottom and the collector tank, at the top, connected by a bundle of vaporizer tubes. Water circulates in this assembly, which is transformed into steam.

Arriving at the boiler, the demineralized and degassed water enters the upper tank then it passes into the lower tank circulating in the evaporator tubes which are heated directly by the flame and the hot gases produced by the burners.

The fluid enters the upper cylindrical body in the form of water and steam: The steam thus generated is collected in the upper tank to pass through a superheater in order to increase its temperature, and the excess water is returned to the lower tank by drop tubes not subjected to heat. Figure 6 schematically shows a water tube boiler:

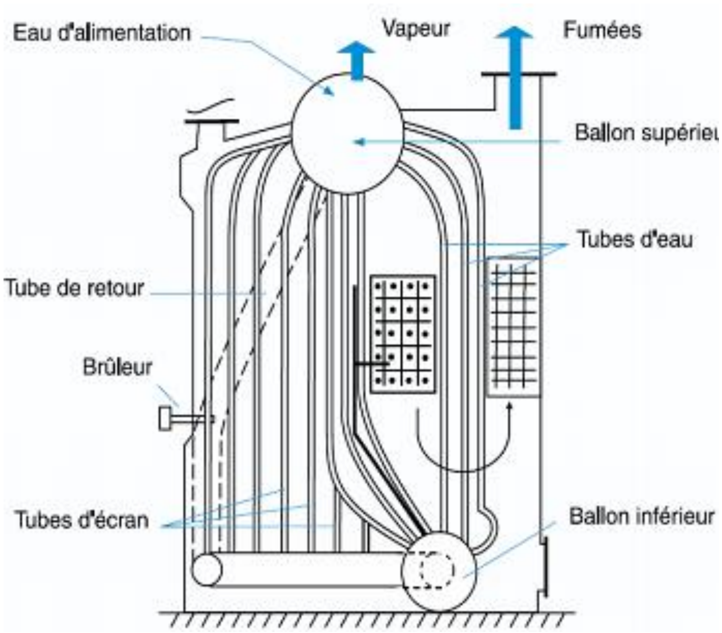


Figure6: Diagram of a water tube boiler

- **Condensers**

The condenser is a heat exchanger which allows a gaseous fluid to pass into the liquid state by releasing heat to a surface kept cold using a refrigerant fluid; which can usually be air or water.

There are two types of condensers;

Condensers by surface: these types operate without direct contact between the vapor to be condensed and the refrigerating fluid, an exchange surface interposing between them;

Mixing condensers: these types operate with total mixing between the vapor to be condensed and the refrigerant fluid. However, the latter remain little used due to the impossibility of mixing between steam and cooling water.

- **Alternators**

In thermal power plants, we have mechanical energy which is converted into electrical energy. We then speak of electromechanical conversion. One of the most used converters today is the alternator.

The alternator, in fact, is a generator of electricity which produces a variable voltage over time, according to the physical principle of conduction.The alternator, as shown in Figure 7, is composed of a fixed part (the stator), and a moving part (the rotor). Generally, the electromagnet is the rotor and the coil is the stator.

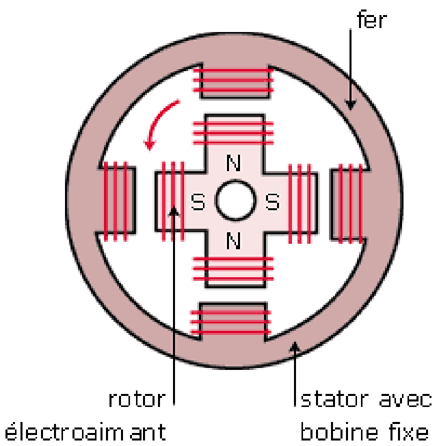


Figure7: Diagram of an industrial alternator

- **Transformers**

The electrical transformer is a converter which is used to transform electrical energy delivered by an alternative electrical energy source into another electrical energy whose voltage is different. This is composed of a core and at least two coils of copper wires not touching each other and both having a different number of windings. The coil where the current arrives is called the "primary coil", the one which produces another voltage is called the "secondary coil". Some transformers have several secondary windings to provide several output voltages. Figure 8 schematically shows an electrical transformer made up of two coils:

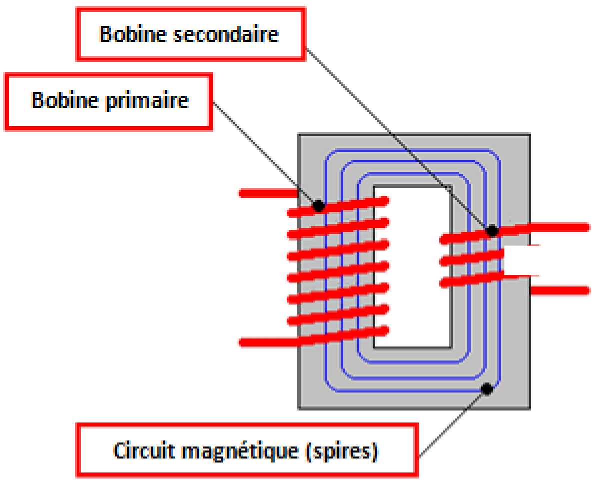


Figure8: Diagram of an electrical transformer

There are different types of thermoelectric power plants. The principle is almost the same; The production of electricity in a thermal power station is done according to a process which allows primary energy coming from a fuel to produce steam which drives a turbine which in turn allows it to power an alternator and therefore produce current. electric.

CHAPTER 2: OPTIMIZATION OF STEAM PRODUCTION FOLLOWING THE DMAIC METHOD

Improving the energy efficiency of a system requires an energy study whose objective is to determine the origin of the main losses in order to subsequently try to analyze them, reduce them and propose corrective actions.

This chapter deals with an overall analysis of losses using the method **DMAIC**. The results obtained previously will be used to suggest solutions aimed at minimizing losses and improving the energy efficiency of the process.

2.1 DMAIC methodology

DMAIC is a problem-solving approach that makes it possible to achieve the objectives of Lean Six Sigma (customer satisfaction, economic means, well-being at work or environmental protection objectives).

It is an experimental, analytical and scientific investigation method carried out in project mode. It is also the approach that any good practitioner (whether a doctor or a mechanic) employs for long-term problem solving.

In French, the word DMAIC is the abbreviation of Define, Measure, Analyze, Improve and Control.

- **Define**

This first phase consists of defining the problem (optimizing).

The main objective of this first step is to define the framework for improving the project, in other words, what we should focus on.

- **Measure**

This step aims to measure the factors that influence the definition problem.

For the measurement to be effective, it must be precise, reproducible and stable.

- **Analyze**

Analysis is an investigative investigation, where it is necessary to understand the root cause of the problem being addressed in order to be able to develop a corrective plan. This step also includes the reasons for these defects.

- **Improve**

The purpose of the improvement phase is to determine the best solution to address the cause of the problem. This is where it can take the longest.

- **Control**

Practically the results are not always immediate, but this last step consists of checking whether the chosen solution is satisfactory. Monitoring is a continuous improvement effort to ensure that you don't look back.

2.2 Application of the DMAIC method on CTE

2.2.1 Step One: Define

The first step is to define the problem to be solved. Continuous improvement and problem solving tools include the brainstorming method 5why method, SIPOC and Ishikawa.

- Brainstorming

Techniques for finding original ideas in meetings, where everyone spontaneously makes suggestions.

- The 5Why method

It is a method which makes it possible to carry out an analysis of the situation based on systematic questioning; the approach consists of collecting and analyzing all the relevant information available by asking as many questions as possible. The goal is the exhaustive and rigorous collection of data (What, Who, Where, When, How, How much, Why)

- The Ishikawa method

The Ishikawa method is a graphical representation in a diagram. It looks like a fish bone. This is achieved thanks to a structure that links the cause and its effect (faults, breakdowns, malfunctions, etc.). This performance earned him the nickname "fishbone".

- The SIPOC method

SIPOC is the acronym for Supplier, Inputs, Process, Outputs and Customers. In the Six Sigma methodology, SIPOC is used during the first step of DMAIC, define, in order to describe the process whose quality we want to improve.

Application of methods

- Brainstorming

	SIGHT project for the thermoelectric plant	CR n°1: 07/11/2021

Participants	**Business**	**Occupation**
Ms. Hammami Malek	Tunisian Company of Refining Industries	Head of Control and Optimization Department
Ms. Ammar Imene	Higher Institute of Technological Studies of Bizerte	Technologist and IEEE Senior member
Mr Temimi Nourallah	Higher Institute of Technological Studies of Bizerte	Student IEEE Member
Ms. Zaghdoudi Mouna	Higher Institute of Technological Studies of Bizerte	Student IEEE Member

Agenda		**Responsible**
Previous actions	Analysing results of preliminary and in-depth audits	Temimi Nourallah and Zaghdoudi Mouna
Progress of the schedule	Analysis completed	Temimi Nourallah and Zaghdoudi Mouna
Approval of the forecast	approved forecast	Ms. Hammami Malek and Ms. Ammar Imene
New needs	Optimization of CTE	Temimi Nourallah and Zaghdoudi Mouna
Means of implementation	Data and information provided by STIR	Ms. Hammami Malek
Validation of the CR	CR Validated	Ms. Hammami Malek and Ms. Ammar Imene

Agreements reached

After the brainstorming carried out during this meeting we agreed to focus on the most critical process: the steam production process (Boilers)

Conclusions

An optimization of the steam production process will be carried out according to the DMAIC Lean six sigma methods.

Next activities	**Responsible**
1- Define the problems 2- Measure the intervening factors 3- Detailed analysis 4- Process improvement 5- Process control (if possible)	Temimi Nourallah and Zaghdoudi Mouna

Written by: Temimi Nourallah and Zaghdoudi Mouna

Signature

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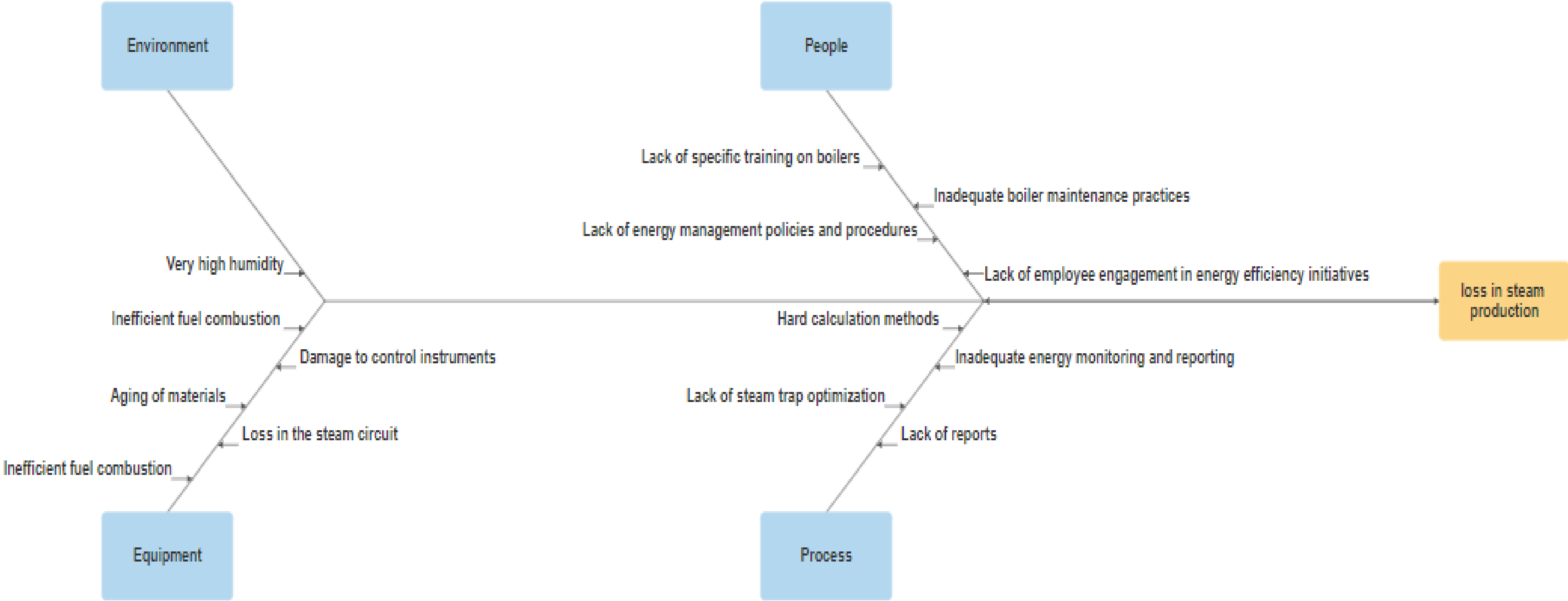
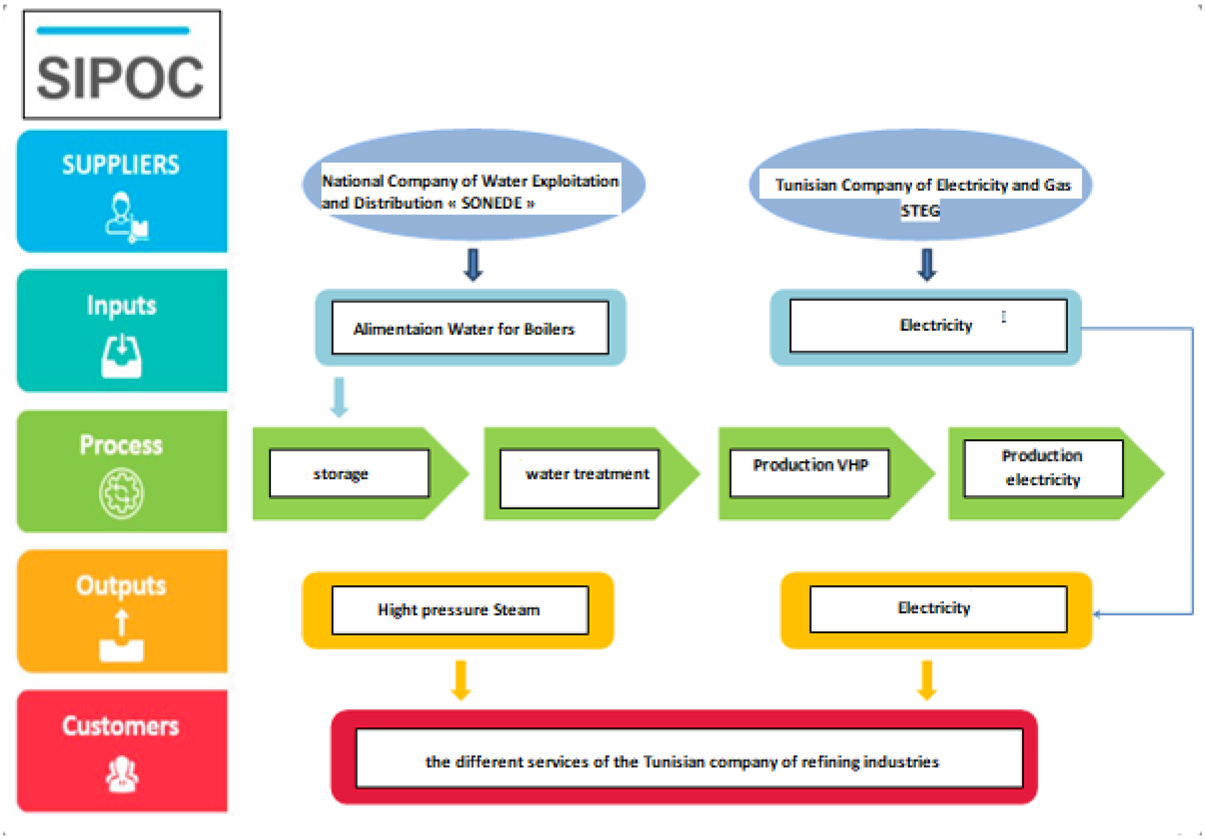
- 5why method

Who ?	**Who is affected by the problem?** • The Tunisian company of Refining Industries "STIR" in particular and African Companies in General **Who is responsible for the mission?** • The head of the control and optimization department: Ms. Malek Hammami • IEEE ISET Bizerte students: Bachelor's degree in mechanical engineering, specializing in industrial maintenance And Master degree in Supply chain management • Academic supervisor and IEEE Senior : Mrs. Imene Ammar
What ?	**What is the problem?** • Unorganized information and energy losses in the STIR thermoelectric power station
Or ?	**Where does the problem appear?** • At the STIR thermoelectric power station
When ?	**When does the problem appear?** • After an energy audit mission.
How ?	**How to solve the problem?** • By carrying out the necessary optimization of the plant from an energy point of view.
For what ?	**Why solve the problem?** • To organize data from the CTE. • To promote the energy performance of the STIR thermoelectric power station • For a good reputation of the company image. • To ensure the sustainability of the company • To suggest possible improvements

- The Ishikawa method


Environment
People
Lack of specific training on boilers
Inadequate boiler maintenance practices
Lack of energy management policies and procedures
Very high humidity
Lack of employee engagement in energy efficiency initiatives
loss in steam production
Inefficient fuel combustion
Hard calculation methods
Damage to control instruments
Inadequate energy monitoring and reporting
Aging of materials
Lack of steam trap optimization
Loss in the steam circuit
Lack of reports
Inefficient fuel combustion
Equipment
Process

- <u>SIPOC method</u>



2.2.2 Step Two: Measure

This involves measuring the factors affecting the steam circuit in the CTE. As a result, a loss calculation will be established in order to know the energy wasted over a well-defined period.

All calculations based on energy auditing results.

<u>A- Energy study of steam losses</u>

- Arithmetic average of hourly mass flow:

$$\bar{X} = \frac{\sum Mass\ flow\ per\ day}{days}$$

- Average total Producer mass flow:

$$\bar{X}_{TOTALE\ productors} = \sum \bar{X}_{Productors}$$

- Total average mass flow of Consumers:

$$\bar{X}_{TOTALE\ Consumers} = \sum \bar{X}_{Consumers}$$

- Average mass losses:

$$\Delta M = \bar{X}_{TOTALE\ productors} - \bar{X}_{TOTALE\ Consumers}$$

- Average energy losses:

$$\Delta Q = \Delta M \times H$$

- Total average mass losses:

$$\Delta M_{Totale} = \Delta M_{VHP} \times \Delta M_{VMP} \times \Delta M_{VBP}$$

- Total average energy losses:

$$\Delta Q_{Totale} = \Delta Q_{VHP} \times \Delta Q_{VMP} \times \Delta Q_{VBP}$$

- Fuel oil losses:

$$P_{Fuel\ oil} = \frac{\Delta Q_{Totale}}{PCI_{Fuel\ oil}}$$

Setting

Symbol	Indication
$\bar{X}$	**Arithmetic average**
ΔM	**Mass Losses**
ΔQ	**Energy losses**
H	**Enthalpy**
$PCI_{Fuel\ oil}$	**Calorific power**
$P_{Fuel\ oil}$	**Fuel oil losses**

	VHP							VMP							VBP							
	Production		Consumption					Production			Consumption					Production			Consumption			
Mass flow (kg/h)	CH101	CH202	TG I	TG II	R VHP-VM	02 TK1	EMI Statio	TGI	R VHP-VM	RC boiler	R VMP-VB	CTE	Topping	R.C.	R VMP-VB	rbine topp	RC turbine	CTE	CDM	Topping	R.C.	Condensation
March 07-08	15300	11400	19200	5300	200	2000	0	19200	200	1500	4300	8000	4500	4000	4300	0	1000	600	2000	1000	500	1200
March 08-09	13600	13200	19300	5300	200	2000	0	19300	300	1500	4600	8000	4500	4000	4500	0	1000	600	2000	1000	500	1400
March 9-10	13000	13900	19300	5200	300	2000	0	19300	300	1500	4600	8000	4500	4000	4600	0	1000	600	2000	1000	500	1500
March 11-14	14300	13000	20200	4900	300	2000	0	20200	300	1500	5400	8000	4500	4000	5400	0	1000	500	2000	2000	500	1400
March 14-15	14000	13800	20400	4900	400	2000	0	20400	400	1500	5800	8000	4500	4000	5800	0	1000	500	2500	2000	500	1300
March 15-16	15000	11500	19100	5000	400	2000	0	19100	400	1500	4500	8000	4500	4000	4500	0	1000	500	2000	2000	500	400
March 16-17	15600	10800	18900	5100	400	2000	0	18900	400	1500	4300	8000	4500	4000	4300	0	1000	500	2000	2000	500	300
Average (kg/h)	14,4	12,514	19,486	5,1	314	2	0	19,486	329	1,5	4,786	8	4,5	4	4,771	0	1	543	2,071	1,571	500	1,071
Average Total (kg/h)	26914		26900					21314			21286				5771.43			5757.14				
Average mass losses (kg/h)	14.29							28.57							14.29							
Average energy losses (kcal/h	11271							20200							9771.43							
Total mass losses (kg/h)	57.14																					
Total energy losses (kcal/h)	41242																					
Fuel oil losses (kg/h)	4.21																					

2.2.3 Step Three: Analyze

This step is an investigation and interpretation step to determine the causes of the problem. We chose pareto analysis technique to identify most critical problems .

- **Problems Identified :**

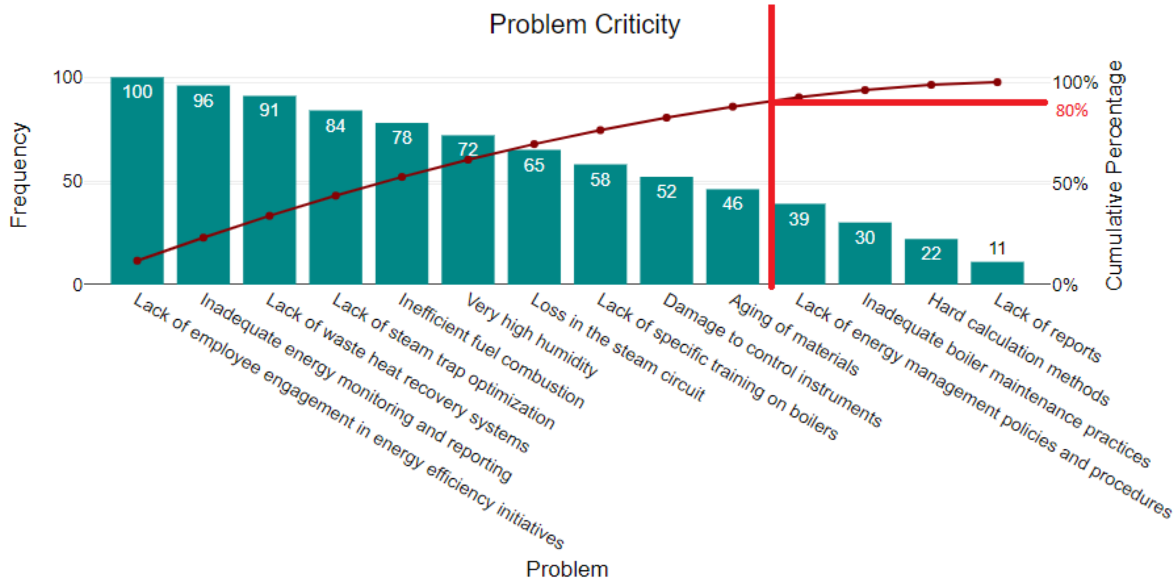
  - Aging of materials
  - Damage to control instruments
  - Lack of specific training on boilers
  - Loss in the steam circuit
  - Lack of reports
  - Hard calculation methods
  - Very high humidity
  - Inadequate boiler maintenance practices
  - Inefficient fuel combustion
  - Lack of steam trap optimization
  - Lack of waste heat recovery systems
  - Lack of energy management policies and procedures
  - Inadequate energy monitoring and reporting
  - Lack of employee engagement in energy efficiency initiatives

- **Scoring Based on Brainstorming and discussion with Company's Staff**

Problem	Score	Explanation
Lack of reports	5	Lack of accurate and timely reporting can make it difficult to identify and address energy-saving opportunities.
Hard calculation methods	5	Inaccurate methods for estimating energy consumption and losses can lead to poor decision-making and missed energy-saving opportunities.
Inadequate boiler maintenance practices	4	Insufficient maintenance can lead to a decline in boiler efficiency and an increase in energy consumption.
Lack of energy management policies and procedures	4	The absence of clear guidelines and procedures for managing energy can hinder efforts to improve efficiency.
Aging of materials	3	Aging materials can lead to leaks and failures, reducing boiler efficiency and increasing energy consumption.
Damage to control instruments	3	Malfunctioning or faulty control instruments can affect boiler operation and efficiency.
Lack of specific training on boilers	3	Inadequate knowledge and skills among boiler operators can impact boiler operation and efficiency.
Loss in the steam circuit	3	Leaks and steam losses in the steam distribution system can reduce boiler efficiency and increase energy consumption.
Very high humidity	3	Excessive moisture in the surrounding environment can cause corrosion and electrical hazards, reducing boiler efficiency and increasing maintenance costs.
Inefficient fuel combustion	3	Inefficient fuel combustion can lead to energy losses and higher emissions.
Lack of steam trap optimization	3	Faulty or improperly sized steam traps can lead to steam losses and energy inefficiency.
Lack of waste heat recovery systems	3	Waste heat from boilers can be used to preheat water or other fluids, reducing energy consumption.
Inadequate energy monitoring and reporting	2	Insufficient monitoring and reporting make it difficult to track progress and identify areas for improvement.
Lack of employee engagement in energy efficiency initiatives	2	Lack of employee engagement can hinder efforts to promote energy-saving behaviors and practices.

- **Pareto Analysis :**

After doing the cumulative percentage analysis based on problem criticity this graph is the result.



2.2.4 Step Four: Improve

This stage can move from theory to application and implement improved solutions detected during the analysis phase. It is also a stage of continuous improvement. Indeed, the FMEA tool is a good choice for analyzing and recommending corrective actions aimed at reducing the occurrence of the cause of the problem identified in the FMEA analysis and in the previous step. We can therefore qualify it as an analysis tool and also an improvement tool.

2.2.4.1 FMEA

FMEA is the Analysis of Failure Modes, Their Effects and their Criticality. It is a quality tool for preventative analysis to identify and address potential causes of defects and failures before they occur. Due to the pooling of information and data, the FMEA method is a rigorous and very effective working method.

Application of the FMEA method will be established on the most critical organ in the CTE, namely the CH101 boiler.

First, each subsystem is decomposed into sets and each set is decomposed into subsets as shown in the table below and the next part consists of filling in the FMEA tables.

Painting3: Constituent elements of the CH101 boiler

Subsystem	Subset	Components
Air circuit	Electric motor	Rotor Stator Fan Terminal box
	Control valve	Valve Spring Membrane Seal Distributor
	Pressure switch	
Fuel circuit	Control valve	Valve Spring Membrane Seal Distributor
	Fuel pump	Motor Pallet bearings Ring
	Bypass valve	
	Pressure switch	
	All or nothing valve	
	Solenoid valve	
Water circuit	Engine	Rotor Stator Fan BearingTer minal box
	Pump	Valve Cover Membrane Seal Body Seat Shaft Lever
Burner	Fuel nozzles	
	Filtered	
	Nozzle	
	Fuel flow regulator	
	Fan motor	
	Fan	
	Preheater	
	Pulleys	
Tubular bundles		

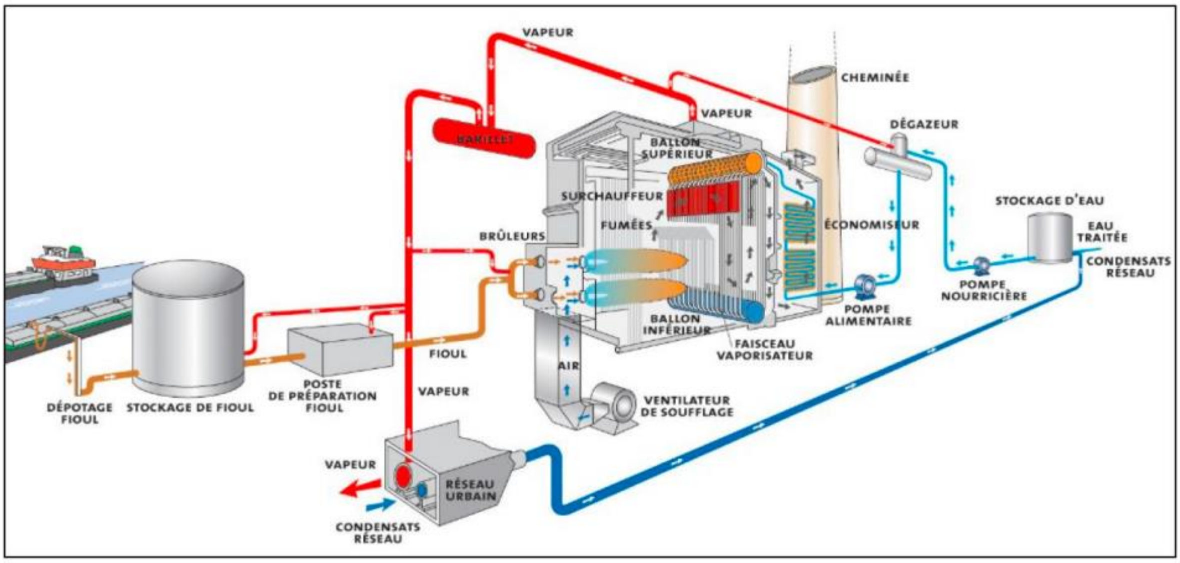


Figure9: Main components of a boiler

FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM										
System: boiler			Sub-system: air circuit			*Operation phase:*				*page 1* *Date:27/11/23*
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**
						F	**G**	**NOT**	**VS**	
Drive motor assembly	Generate rotational torque	Blocking Stopping the engine	Blocking of bearings Lack of power supply Electrical overload Absence of motor ventilation Pressure drop Deterioration of the winding	No ventilation	Visual after disassembly	1	2	4	8	Change bearings Check the electrical circuit Check the power source Do not turn on until it recovers Rewinder
Bearing and transmission shaft assembly	Transmission of rotation to the fan	Bearing wear Shaft vibration and breakage Heating at the level of the bearings	Bad lubrication Bearing damage Bad alignment	No ventilation	Noise Visual after disassembly High temperature	1	2	4	8	Periodic lubrication Change bearings Realign
Fan	Air suction	Degraded operation	Blade deformation Deterioration of the mechanical connection Blade clogging	Reduced ventilation	Noise Overload	1	2	4	8	Change the fan Clean the fan

	FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM					*Operation phase:*				*page 2*
	System: Boiler		Sub-assembly: Control valve							*Date: 27/11/23*
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**
						F	**G**	**NOT**	**VS**	
Flapper	Opening or closing the valve	Valve blocking	Corrosion	Valve blocked (boiler shutdown)	Lack of pressure	1	2	2	4	Changing the valve
Distributer	Air distribution control	Pusher blocking	Failed return spring Pusher seizing	Distributor blocked (valve does not work)	No air pressure	1	2	5	10	Change of distributor
Membrane	Air tank	Defective membrane	High pressure	Low pressure (absence of the closing order)	The valve does not close	2	2	4	16	Changing the membrane
O-ring	Waterproofing	Seal wear	High pressure corrosion	Pressure leak	None	2	2	4	16	Changing the seal
Spring	Closing of the valve by compression of the spring	Loses elasticity movement	Spring fatigue	The valve does not close	None	1	3	4	12	Changing the spring

	FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM					Operation phase				*Page : 3*
	System : Boiler		Sub-system : Fuel circuit							*Date : 27/11/23*
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**
						F	**G**	**NOT**	**VS**	
Bypass valve	Ensures gas flow at technical minimum (load =0)	Dysfunction	Internal rupture of the membrane	Stopping the burners	Low fuel pressure safety pressure switch	1	3	4	12	Change the by-pass valve membrane
Pressure switch	Pressure sensing	No detection	No power Poor pressure switch contact	Burner shutdown	Alarm	1	2	4	8	Change the pressure switch Checking the power supply
All or nothing valve	Opening and closing	Valve blocked	Power circuits (compressed air and power supply)	Burner shutdown	Alarm	2	2	4	16	Checking the power supply to the solenoid valve, distributor,
Solenoid valve	On/off valve control	Solenoid valve failing	Burnt coil Internal deterioration	No valve control	Alarm	1	2	4	8	Change the solenoid valve
Control valve	See the table below									
Fuel pump	See the table below									

	FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM									*Operation phase:*	*page: 4*
	System: Boiler		Sub-assembly: Fuel pump								*Date: 27/11/23*
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**	
						F	**G**	**NOT**	**VS**		
Engine	Drives the pump shaft to rotate	No rotation	Engine out of service	Boiler not starting	Visual	3	4	3	36	Check the electrical circuit Check the power source Don't turn on until it recovers Rewind	
Bearings	Transmits the rotational movement of the motor	Sectioning, blocking	Overload	No start of the boiler	Visual	2	4	3	24	Changing bearings	
Pallets	Suction – Discharge	Wear Break	Very high effort Lack of lubrication cavitation	Stopping the pump	Abnormal noise	2	4	3	24	Change of pallets	
Ring	Product Movement Guide	Wear	Bad assembly Wear	No boiler starting	Visual	3	2	2	12	Change	

	FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM					Operation phase:				page: 5
	System: Boiler		Sub-assembly: Pump							Date: 27/11/23
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**
						F	**G**	**NOT**	**VS**	
Wheel	Suction – Discharge	Wear Break	Very high effort Lack of lubrication cavitation	Stopping the pump	Noise Vibes	1	4	1	4	Periodic lubrication Change
Trees	Transmit power in the form of torque and rotational movement	Vibration Wear	Poor lubrication Overload	Stopping the pump	Vibration analysis	1	3	2	6	periodic lubrication Change Bearings Realign
Trim	Ensures the sealing of the pump, preventing liquid leaks outside	Face wear Wear of joints	Poor water and oil quality	Stopping the pump	Water or oil leak	2	3	1	6	Trim change
Streamer	Product Movement Guide	Wear	Cavitation Loaded water	Degraded function	Noise Cavitation	3	1	1	3	Change
Volute	Extend the hydraulic effect of the wheel	Wear	Cavitation Loaded water	Degraded function	Noise Cavitation	3	1	1	3	Cleaning the pump

	FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM										
	System: Boiler		Subassembly: Electric motor			*Operation phase:*				*page: 6*	*Date: 27/11/23*
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**	
						F	**G**	**NOT**	**VS**		
Rotor	Transforms electrical energy into mechanical energy (rotation)	Heating of the bearings	Poor bearing lubrication Bearing wear	Engine shutdown	Temperature Amperage	2	4	1	8	check the electrical circuit	
Stator	Transforms electrical energy into magnetic	Loss of insulation Warming up	Failure to tighten and break power cables	Engine shutdown	Temperature of the 3 reels Amperage Insulation test	2	4	1	8	Changing the power cables	
Fan	Cool the engine	Wear Broken	Unbalanced	No stopping	Noise	1	2	2	4	Verification Cleaning	
Rolling	Ensures rotational movement	Wear Breakup	Lack of lubrication Bad alignment	Stopping the engine	Noise Temperature Vibration	1	4	1	4	Changing bearings	
Terminal box	Ensures power to the motor	Sealing (short circuit)	Insulation fault	Engine shutdown	Insulation control	1	3	4	12	Check the short circuit	

FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM		*Operation phase:*	*page: 7*
System: Boiler	Subset: Burner		*Date: 27/11/23*

Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality** F	G	NOT	VS	**Actions Fixes**
Fuel nozzles	Create a movement whirlpool of the fuel + air mixture	Wrong orientation of beveled surfaces	Incomplete combustion	Presence of carbon monoxide in the exhaust fumes	Smoke analyzer (CO, SO, O2)	1	4	3	12	Adjusting the nozzles
Filtered	Extract materials solids in fuel	Clogging	Poor quality fuel	Fuel pressure drop	Visual	1	3	1	3	Changing the filter
Nozzle	Spray the fuel through the burner	Bad spraying	Opening clogged	Bad combustion	Visual	3	4	2	24	Periodic maintenance
Fuel flow regulator	Regulates fuel flow	No rotation	Unpowered servomotor	No regulation	Visual	1	2	2	4	Calibration Change
Fan motor	Train ventilation	No rotation	Grilled winding	No fan rotation	Visual	1	4	2	8	Check the electrical circuit
Fan				No fan rotation	Hearing	1	2	2	4	Check the power source Cleaning the ventilator
Preheater	Preheat the fuel during cold starting	No heating	Short circuit resistance	Bad combustion	multimeter	1	3	3	9	Cleaning Reset Replacement
				Bad combustion	multimeter	1	2	3	6	

	FMEA MACHINE – ANALYSIS OF FAILURE MODES, THEIR EFFECTS AND THEIR CRITICISM										*Operation phase:*	*page: 8*
	System: Boiler		Subsystem: Tubular bundles									*Date: 27/11/23*
Element	**Function**	**Failure mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective actions**		
						F	**G**	**NOT**	**VS**			
Tubes	Convey water and steam	Inlay	Deposit of impurities on the heating surfaces	Poor heat conduction. Local overheating of the tube. Tube rupture.	Analyze samples at laboratory level (PH, Conductivity)	1	5	2	10	Purge the bottom of the boiler		
		Prime	Entrainment of mineral salts by steam	Erodes the tubes. Clogging of turbine blades	Analyze samples at the laboratory level	1	5	2	10	Stripping		
		Corrosion	Oxidation of metal with release of electrons	Slow decrease in tube thickness	Analyze samples at the laboratory level	2	5	3	30	Change the damaged part of the tubes		

Analysis of the CH101 boiler of the thermoelectric power station

In this analysis, the organs are classified in descending order according to their criticality, the percentage of criticality and the cumulative percentage of each element.

The following table presents the criticalities of the elements.

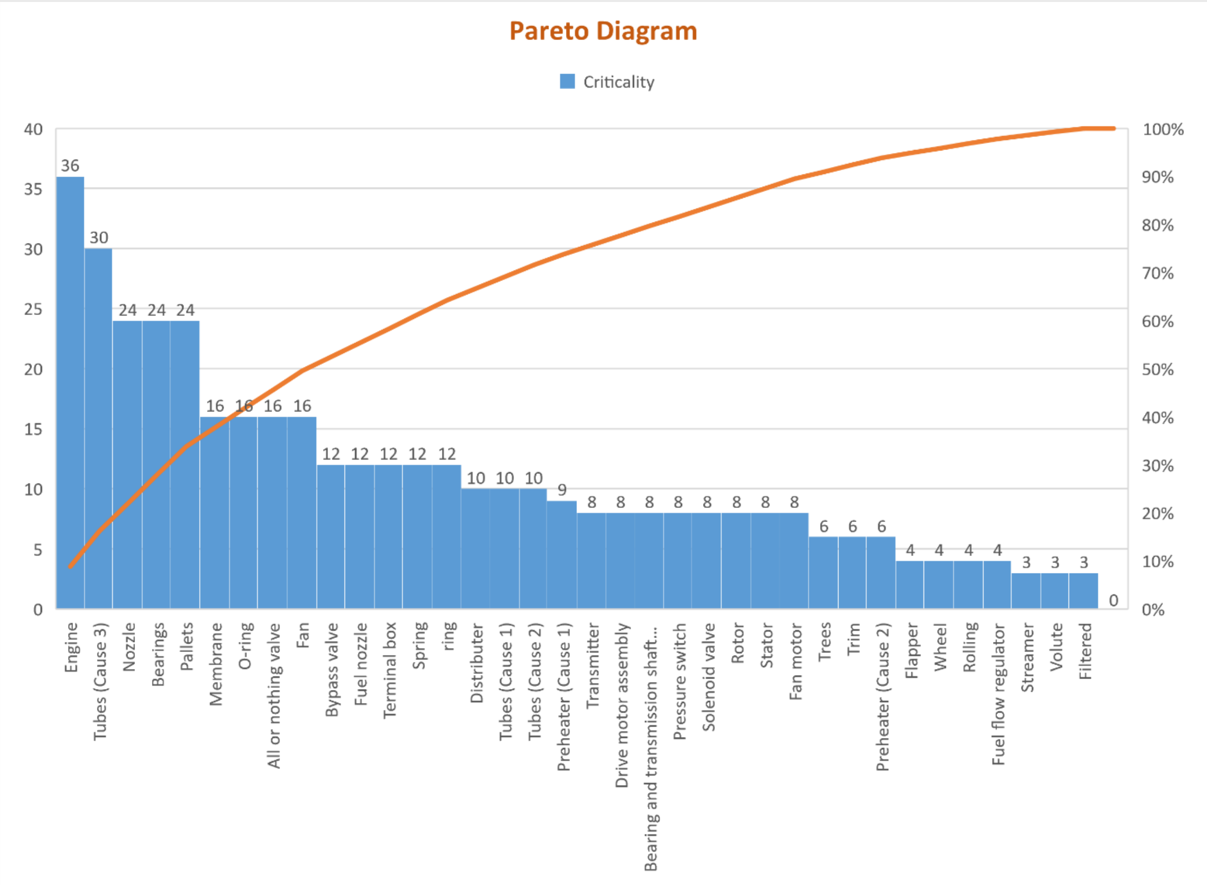
Painting4: Assessment of the criticality of the different elements

Storage	*Elements*	*Criticality*	*Percentage*	*% Cumulative*
1	Engine	36	8.82	8.82
2	Tubes (Cause 3)	30	7.35	16.18
3	Nozzle	24	5.88	22.06
4	Bearings	24	5.88	27.94
5	Pallets	24	5.88	33.82
6	Membrane	16	3.92	37.75
7	O-ring	16	3.92	41.67
8	All or nothing valve	16	3.92	45.59
9	Bypass valve	12	2.94	48.53
10	Fuel nozzle	12	2.94	51.47
11	Terminal box	12	2.94	54.41
12	Spring	12	2.94	57.35
13	ring	12	2.94	60.29
14	Distributer	10	2.45	62.75
15	Tubes (Cause 1)	10	2.45	65.20
16	Tubes (Cause 2)	10	2.45	67.65
17	Preheater (Cause 1)	9	2.21	69.85
18	Fan	8	1.96	71.81
19	Transmitter	8	1.96	73.77
20	Drive motor assembly	8	1.96	75.74
21	Bearing and transmission shaft assembly	8	1.96	77.70
22	Pressure switch	8	1.96	79.66
23	Solenoid valve	8	1.96	81.62
24	Rotor	8	1.96	83.58
25	Stator	8	1.96	85.54
26	Fan motor	8	1.96	87.50
27	Trees	6	1.47	88.97
28	Trim	6	1.47	90.44
29	Preheater (Cause 2)	6	1.47	91.91
30	Flapper	4	0.98	92.89
31	Wheel	4	0.98	93.87
32	Fan	4	0.98	94.85
33	Rolling	4	0.98	95.83

34	Fuel flow regulator	4	0.98	96.81
35	Fan	4	0.98	97.79
26	Streamer	3	0.74	98.53
37	Volute	3	0.74	99.26
38	Filtered	3	0.74	100.00
	SUM	408	100.00	

ABC analysis of the CTE CH101 boiler subassemblies

The PARETO diagram provided below groups the elements according to the importance of their-criticality.



The curve makes it possible to divide the elements of the system studied into three classes:

Class A: representing the most critical elements (C >16), this class represents up to 45.59% of the cumulative criticality.

Class B: medium criticality elements (4≤VS≤16), this class represents up to 91.91% of the cumulative criticality.

Class C: of the least critical elements (C < 4), this class from 92.89% of the cumulative criticality.

After determining the major causes of failures as well as their effects, a table of corrective actions relating to the FMEA analysis is necessary;

Painting5: Corrective actions

Elements	***Preventive action***	***Frequency***	***Responsible***
Engine (Fuel pump)	Check-up – Maintenance	6 months	Electrician
	Check the electrical circuit Check the source Does not turn on until it recovers	Every startup	Electrician
	Rewinding	12 months	
Tubes (Cause 3)	Checking the chemical composition of the water in the tubes	3 months	Laboratory
	Checking the cavitation change of the damaged part of the tubes	3 months	Mechanic
Nozzle	Periodic maintenance	6 months	Mechanic
	Changing the Nozzle	24 Months	
Bearings (Fuel pump)	Changing bearings	12 months	Mechanic
Pallets (Fuel pump)	Change of pallets	12 months	Mechanic
Membrane (Regulation valve)	Changing the membrane	36 Months	Mechanic
O-ring (Regulation valve)	Checking the tightness	6 months	Mechanic
	Changing the seals	12 months	
All or nothing valve	Checking the power supply to the solenoid valve, distributor.	3 months	Electrician

At this point, the problems have been clearly identified. The next step is to improve the data entry and manipulation interface.

2.2.4.2 Input interface

With a view to improving the interface for handling, saving and calculating data, a platform has been created to facilitate the user in entering data and calculating boiler balances and losses.

The professional website which carries out this operation will have limited access to STIR control agents.

In addition, this site represents a database for the company whose histories are automatically saved.

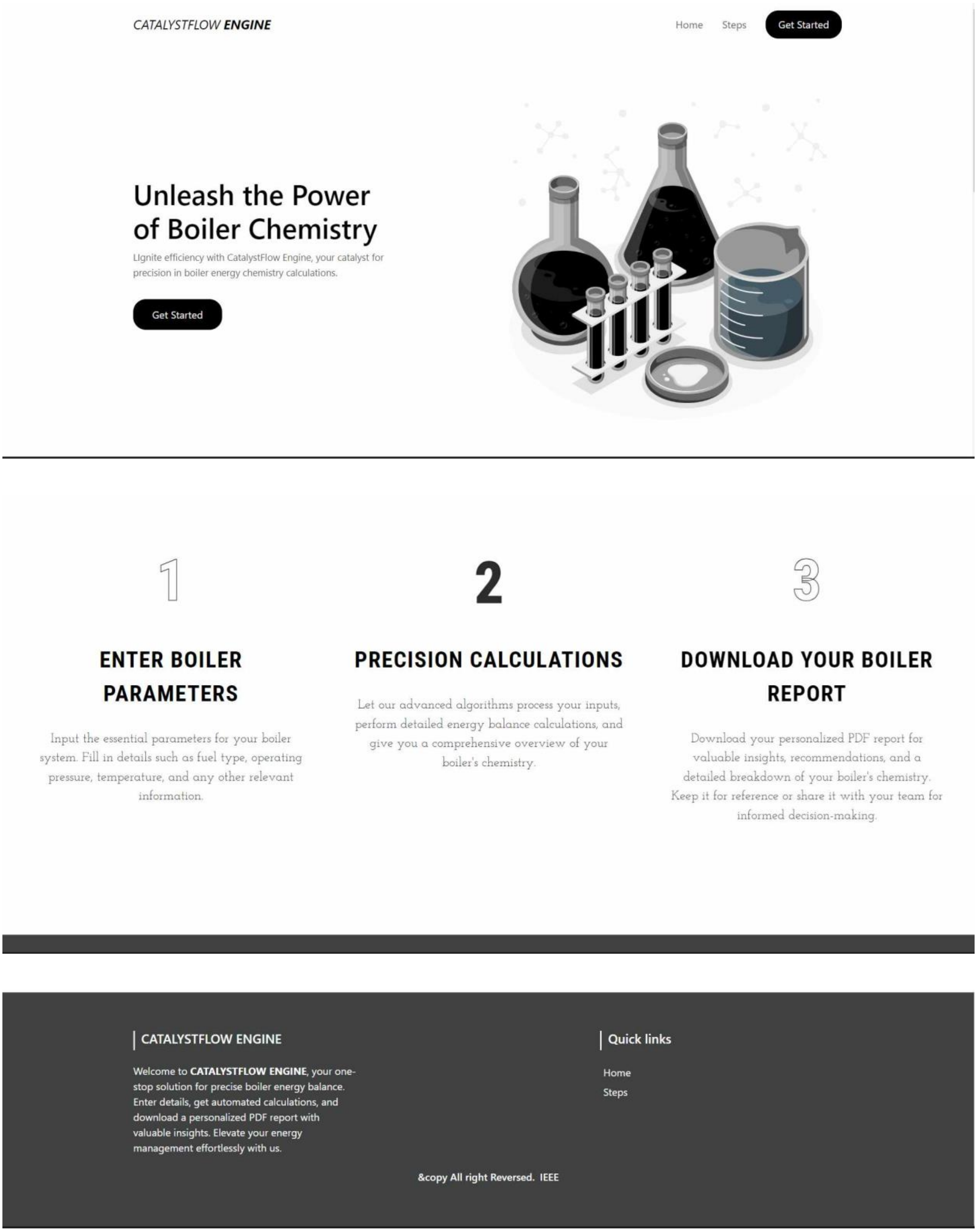


Figure10: Interface of the boiler energy efficiency calculation.

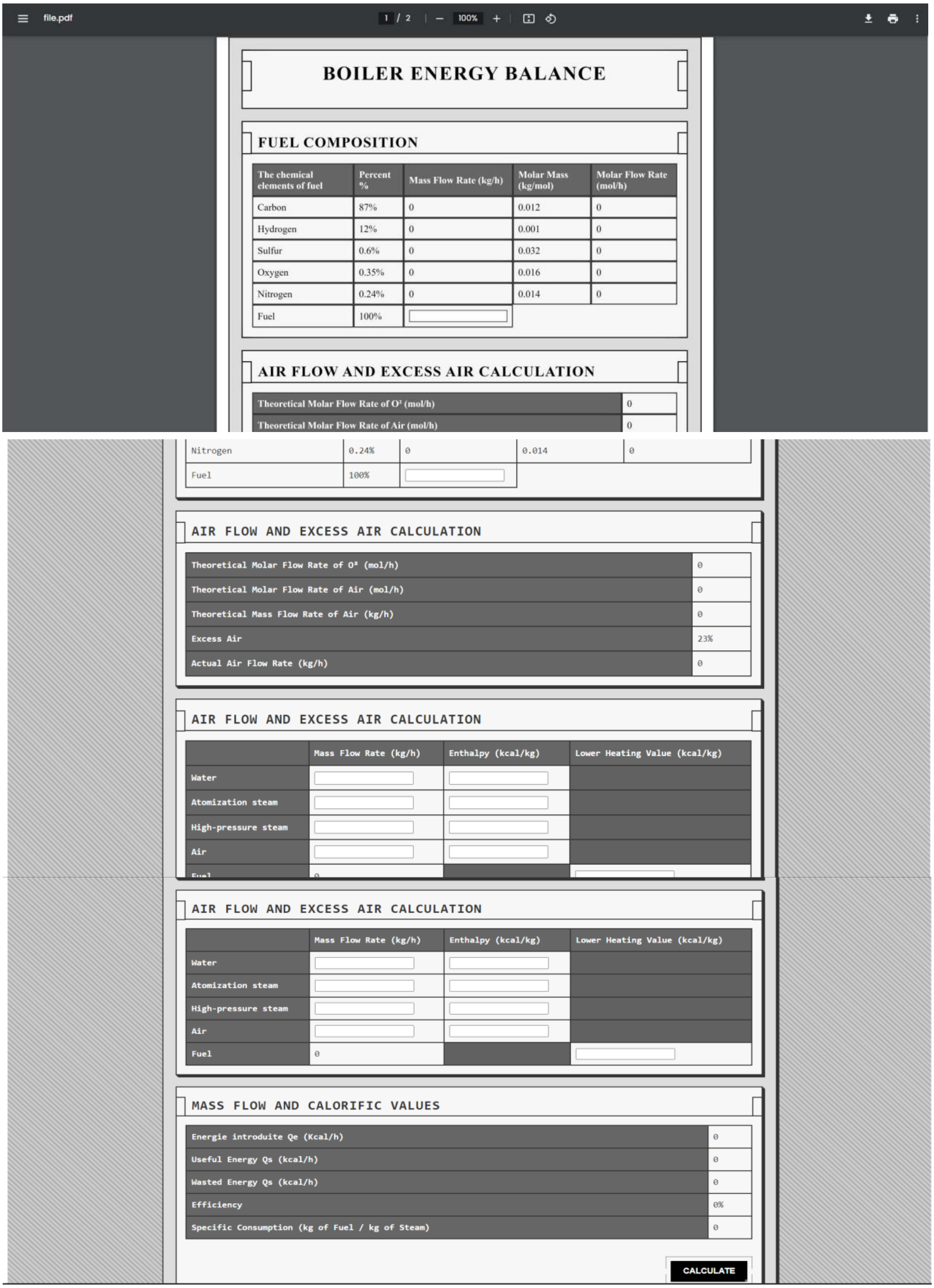


Figure11: Calculations

2.2.5 Step Five: Control

The fifth stage of the DMAIC process is the control and monitoring phase. It follows the "improvement" phase which makes it possible to implement new solutions chosen after an in-depth study of certain problems in the CTE. This step is complex, and she must observe the current situation by comparing it with the initially unsatisfactory situation to confirm the success of the approach. But the achievement of this step remains dependent on the results achieved after the improvement.

Many factors can influence the energy efficiency of a power plant; this is mainly the role of the DMAIC method which aims to identify and analyze them. This method helped reduce the number of variables involved in the process, as any problems can arise from this variability. Once the causes have been identified and a solution developed, the control mechanism can continue the process of continuous improvement.

CHAPTER 3 : Entrepreneurial Aspects & SDG's Alignement :

3.1 Alignement with the SDG's

Our startup's mission to develop innovative fossil energy solutions that enhance efficiency, reduce environmental impact, and promote sustainable development aligns with several of the Sustainable Development Goals (SDGs). Specifically, our work contributes to the following SDGs:

- SDG 3: Good Health and Well-being: Our solutions can help to improve air quality and reduce exposure to harmful emissions, thereby contributing to better health outcomes for individuals and communities.
- SDG 6: Clean Water and Sanitation: Our solutions can help to reduce water consumption and wastewater generation in the energy sector, contributing to the conservation and protection of water resources.
- SDG 8: Decent Work and Economic Growth: Our solutions can create new jobs and opportunities in the fossil energy sector, while also promoting sustainable practices that can contribute to long-term economic growth.
- SDG 9: Industry, Innovation and Infrastructure: Our work involves research and development, technology innovation, and the development of new infrastructure for fossil energy production and utilization.

- SDG 11: Sustainable Cities and Communities: Our solutions can help to improve energy efficiency and reduce greenhouse gas emissions in cities, contributing to sustainable urban development.
- SDG 12: Responsible Consumption and Production: Our commitment to resource efficiency, waste reduction, and pollution prevention aligns directly with this SDG.
- SDG 13: Climate Action: Our work directly addresses the challenge of climate change through the development of fossil energy solutions that minimize environmental impact.
- SDG 15: Life on Land: Our solutions can help to reduce deforestation and land degradation associated with fossil fuel extraction and processing.
- SDG 17: Partnerships for the Goals: Our collaboration with partners from the public and private sectors is essential for achieving our goals and contributing to the broader SDG agenda.

In particular, our work aligns closely with SDG 12, which aims to ensure sustainable consumption and production patterns. Our fossil energy solutions are designed to reduce the environmental footprint of the energy sector, while also contributing to resource efficiency and waste reduction. Additionally, our collaboration with partners and stakeholders across the value chain can help to promote sustainable practices and foster a circular economy approach to fossil energy use.

Finally, our work aligns with SDG 17, which calls for strengthened global partnerships to achieve the SDGs. Our collaboration Tunisian Company of refining industries is crucial for accelerating the adoption of our solutions and promoting sustainable practices across the fossil energy sector. By working together, we can help to create a more sustainable and equitable future for all.

3.2 Startup creation :

CatalystFlow Engine, stands as a pioneering startup dedicated to revolutionizing the optimization of fossil energy. With a mission to enhance the efficiency of energy systems, particularly boilers, CatalystFlow employs a comprehensive approach. The integration of Failure Modes and Effects Analysis (FMEA) into preventive maintenance strategies underscores the commitment to reliability and longevity in energy infrastructure. The startup's digital platform serves as a catalyst for change, offering users a sophisticated tool for precise energy efficiency calculations. Through a user-friendly website, CatalystFlow provides invaluable insights, empowering industries to make informed decisions, reduce operational risks, and contribute to a sustainable energy future. As CatalystFlow Engine looks back on its first year, it eagerly anticipates a future marked by innovation, collaboration, and transformative solutions in the realm of fossil energy optimization.

Catalystflow Engine

UNLEASH THE POWER OF BOILER CHEMISTRY

3.3 Business Model Canvas	Designed for:	Designed by:	Date:	Version:
	SIGHT & R8 Challenge	IEEE ISET Bizerte SB	29/11/2023	1.1

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Boiler manufacturers and equipment suppliers • Energy efficiency consulting firms • Research institutions and academia • Industry associations and government agencies • Technology partners for data analytics and visualization	• Conducting FMEA analysis for various boiler types and applications • Developing and maintaining the web application for boiler efficiency calculations • Providing preventive maintenance services and onsite support • Conducting energy efficiency audits and optimization recommendations • Integrating boiler efficiency monitoring systems	• Proactive maintenance of boilers through FMEA analysis • Enhanced boiler efficiency and cost savings • Reduced environmental impact through optimized boiler operations • Improved safety and reliability of boiler systems • Comprehensive web application for detailed boiler efficiency calculations	• Dedicated customer support team for technical assistance and troubleshooting • Regular maintenance check-ups and performance monitoring • Online customer portal for access to detailed efficiency reports and maintenance schedules • Customer training and workshops on boiler efficiency optimization • Proactive communication and feedback mechanisms	• Industrial companies operating boilers for various purposes • Oil and gas refineries • Power generation plants • Manufacturing facilities with substantial boiler usage • District heating companies

	Key Resources • Team of experienced engineers and data scientists • Proprietary FMEA analysis software and web application • Partnership network with boiler experts and energy efficiency consultants • Access to industry data and benchmarks • Strong relationships with boiler manufacturers and equipment suppliers		**Channels** • Direct sales to industrial companies and energy sector clients • Collaboration with energy efficiency consulting firms • Partnerships with boiler manufacturers and equipment suppliers • Online presence and lead generation through industry-specific platforms • Attending industry events and conferences	

Cost Structure • Salaries for engineers, data scientists, and customer support staff • Software development and maintenance costs • Marketing and sales expenses • Travel and accommodation costs for client visits and conferences • Partnership fees and collaboration costs	**Revenue Streams** • Subscription fees for FMEA analysis and web application access • Maintenance contracts for preventive maintenance services • Consulting fees for energy efficiency audits and optimization recommendations • Data analytics and reporting services • Integration of boiler efficiency monitoring systems

3.4 Logic Model

Project Mission :

Our mission is to empower communities through innovative fossil energy solutions that enhance efficiency, reduce environmental impact, and promote sustainable development.

Inputs	Activities	Outputs	Outcomes
• Expertise in boiler maintenance and efficiency analysis • Strong relationships with boiler manufacturers and equipment suppliers • Access to industry data and benchmarks	• Conduct FMEA analysis to identify potential boiler failures and preventive maintenance actions • Develop and maintain a web application for detailed boiler efficiency calculations • Provide preventive maintenance services and onsite support • Conduct energy efficiency audits and optimization recommendations • Integrate boiler efficiency monitoring systems	• Improved boiler efficiency • Reduced maintenance costs • Reduced environmental impact • Improved safety and reliability of boiler systems • Comprehensive data on boiler performance and efficiency	• Increased profitability for industrial companies and energy sector clients • Reduced reliance on fossil fuels • Improved public health and environment • Enhanced reputation and brand recognition for the startup

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Environmental Implications
• Reduced greenhouse gas emissions.
• Reduced fossil energy consumption
• Reduced air pollution
• Reduced water consumption
• Improved water quality
• Positive impact on the environment and public health</td></tr>
<tr><td colspan="4">Community Buy-In and Involvement
• Comprehensive Community Engagement Plan
• Partnerships with Local Stakeholders
• Community Assessment Data Gathering
• Incorporation of Community Input
• Training and Capacity Building
• Empowerment of Community Leaders
• Clear Communication Channels
• Evaluation and Adaptation</td></tr>
</table>

3.5 External Environment "PESTEL Analysis"

Political:	Economic:	Social:
Collaborating with STIR, a leading player in the refining industry, would provide our startup with access to valuable resources and expertise, including: • Access to STIR's infrastructure, facilities, and equipment, allowing us to test and validate our fossil energy solutions in real-world settings. • Knowledge and insights from STIR's experienced engineers and technicians, enhancing our ability to develop and implement innovative solutions. • Opportunities to expand our market reach and enhance our credibility by leveraging STIR's reputation and established customer base. • The potential for joint innovation and development of new and improved fossil energy solutions, combining our startup's innovative ideas with STIR's industry expertise.	• Economic growth: A growing economy provides a larger market base and increased demand for our solutions. Economic downturns can reduce demand for energy consumption, impacting your startup's revenue and potential for expansion. • Energy prices: Fluctuations in energy prices can affect the cost-competitiveness of our fossil energy solutions. High energy prices can increase demand for our solutions, while low prices may make your solutions less competitive. • Consumer spending patterns: Consumer purchasing power and spending habits can influence demand for our solutions. Economic downturns can reduce consumer spending on energy-related products and services.	• Public perception of fossil energy: Public opinion towards fossil energy can impact the adoption of our solutions. Negative perceptions can make it more challenging to gain market acceptance and support. • Environmental concerns: Growing environmental concerns and the push for sustainability can influence consumer choices and government policies. our startup should emphasize the environmental benefits of our solutions and demonstrate their contribution to sustainability goals. • Community engagement: Building strong relationships with local communities affected by our operations can foster trust, address concerns, and enhance the social acceptance of your solutions.

Technology:	Environmental:	Legal:
• Advancements in renewable energy: Rapid advancements in renewable energy technologies can pose a competitive threat to your fossil energy solutions. our startup should continuously innovate and differentiate its solutions to maintain a competitive edge. • Technological innovation in fossil energy: Innovation in fossil energy technologies can improve efficiency, reduce environmental impact, and enhance the sustainability of our solutions. Stay up-to-date on emerging technologies and explore opportunities to integrate them into our solutions. • Regulatory requirements for technological advancements: Government regulations may mandate or incentivize the adoption of specific technologies. our startup should comply with these regulations and consider incorporating them into our solutions to gain a competitive advantage.	• Environmental regulations and standards: Stringent environmental regulations can increase costs associated with compliance and potentially limit the scope of our operations. our startup should stay informed about environmental regulations and develop strategies to minimize environmental impact. • Resource availability and sustainability: The availability and sustainability of fossil fuel resources can impact the long-term viability of our business. Explore opportunities to diversify our energy sources and develop solutions that promote resource efficiency. • Climate change and environmental impact: The growing impact of climate change and public awareness of environmental issues can influence consumer choices and government policies. our startup should demonstrate the environmental responsibility of our solutions and contribute to sustainability efforts.	• Intellectual property protection: Strong intellectual property protection can safeguard our innovations and prevent competitors from copying our solutions. Invest in protecting our intellectual property through patents, copyrights, and trademarks. • Regulatory compliance: Complying with all applicable laws, regulations, and standards is crucial to avoid legal challenges and maintain a positive reputation. Regularly review and update our compliance practices to stay abreast of changing regulations. • International trade agreements and tariffs: Trade agreements and tariffs can affect the cost and ease of importing and exporting raw materials, equipment, and finished products. Stay informed about trade policies that may impact our operations.

3.6 Risk Analysis

What is the risk?	What is the potential impact of the risk?	How will you mitigate your risk?
Stringent environmental regulations and policies	• Increased costs associated with compliance with environmental regulations • Potential restrictions on the use of certain fossil energy technologies • Reduced profitability and competitiveness of the startup	• Stay up-to-date on emerging environmental regulations and policies • Proactively implement sustainable practices and technologies to minimize environmental impact • Collaborate with policymakers and regulators to advocate for balanced and pragmatic environmental regulations • Develop contingency plans to adapt to potential changes in environmental regulations
Public perception and resistance to fossil energy	• Difficulty in gaining public acceptance and support for the startup's solutions • Negative publicity and reputational damage • Increased scrutiny and pressure from environmental groups and activists	• Emphasize the environmental benefits and sustainability efforts of the startup's fossil energy solutions • Collaborate with environmental organizations to identify common ground and explore collaborative solutions • Promote the importance of a balanced and diversified energy mix that includes responsible use of fossil fuels alongside renewable energy sources